Optical Searches of Gamma-ray Burst Locations

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Introduction

First discovered in 1973, gamma-ray bursts are cosmic events of very short duration, some of them lasting only a few tenths of a second, whose origin has since been a puzzle. They are now being detected mainly in the hard X-ray range (100–500 keV) by omnidirectional scintillator detectors placed on board spacecraft located in different parts of the solar system (Venera 11 an 12, Pioneer Venus Orbiter, Helios 2, Prognoz 7, ISEE-3 and the Vela satellites).* When a burst is detected by at least 3 spacecraft, triangulation over interplanetary distances is possible through arrival-time analysis of the burst time-histories recorded by the different detectors. Observations by as many as 7 different probes now offer the possibility of unambiguously localizing gamma-ray bursts on the sky to arc-minutes, and sometimes to tens of arc-seconds.

Small error boxes have recently been derived for three southern hemisphere bursts. The 1978 November 19 event is localized in a 5 by 1.5 arcmin high galactic latitude ($\alpha = 1^h16^m$, $\delta = -28°53'$; $b^{II} = -84°$) box which contains two weak radio sources (one is polarized), a very weak X-ray source found by the Einstein satellite as well as several faint optical objects (Cline et al. 1980). In Fig. 1 we show the time history of this event. The extremely intense 1979 March 5 event has now been localized in a very small box (~10 by 20 arcsec) which falls on the edge of the N49 supernova remnant in the Large Magellanic Cloud (Evans et al. 1980). Finally, the brief 1979 April 6 event has been localized in a high galactic latitude box ($\alpha = 23^h11^m$, $\delta = -49°55'$; $b^{II} = -61°$) of about 30 by 40 arcsec with no optical objects visible down to the limit of the SRC Schmidt Survey (22.5 mag). (Laros et al. 1981).

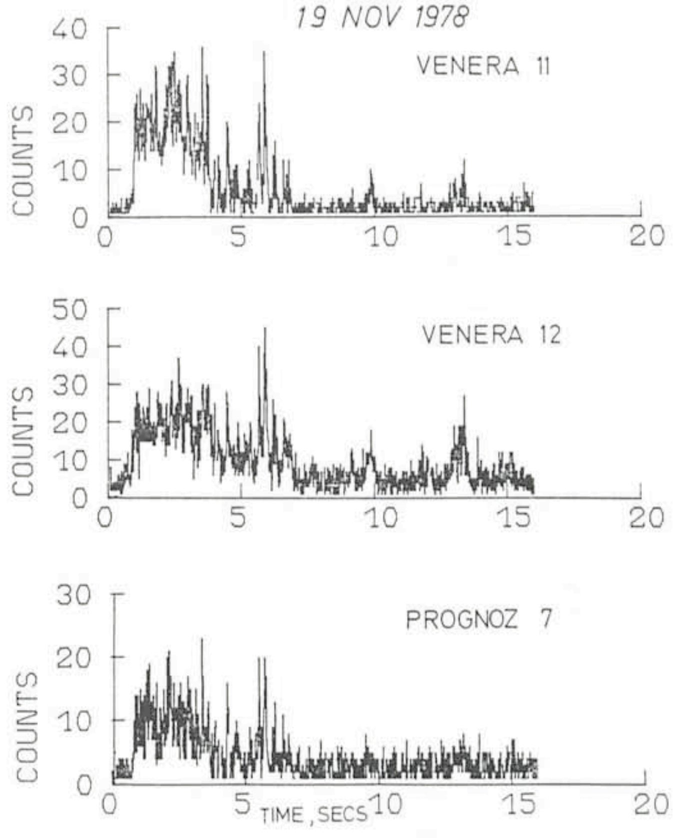

Fig. 1: *Time history of the 1978 November 19 gamma-ray burst event as observed by the Venera and Prognoz CESR detectors. The time resolution is 16 ms and the energy range from 100 keV to 2.5 MeV (from Chambon et al. 1980).*

Optical Observations

In an effort to single out any possible candidate objects which may be associated with the bursts, we have started an optical search programme in these and other boxes by means of photographic observations at the prime focus of the 3.6 m ESO telescope. In spite of the inevitable difficulties with the instrumentation, the weather and the shortage of observing time (!) we have begun to obtain preliminary results. A deep plate of the 1979 April 6 event location taken by H. E. Schuster in September 1980 with the triplet adaptor on pre-sensitized and unfiltered IIIa-J emulsion for 90 minutes has been scanned with the Nice Observatory PDS microphotometer and later analysed with the interactive image processing system at Meudon. The central region is shown in Figure 2, photographed off the COMTAL colour TV display, after smoothing and contrast-enhancing by removing the low density-value tail of the image histogram. The error box is shown as a polygon. We definitely see three objects in the box which are not visible in the J or B Schmidt films of the area. The limit of our plate is at least a full magnitude deeper than the SRC Survey, or about 23.5 to 24 magnitude.

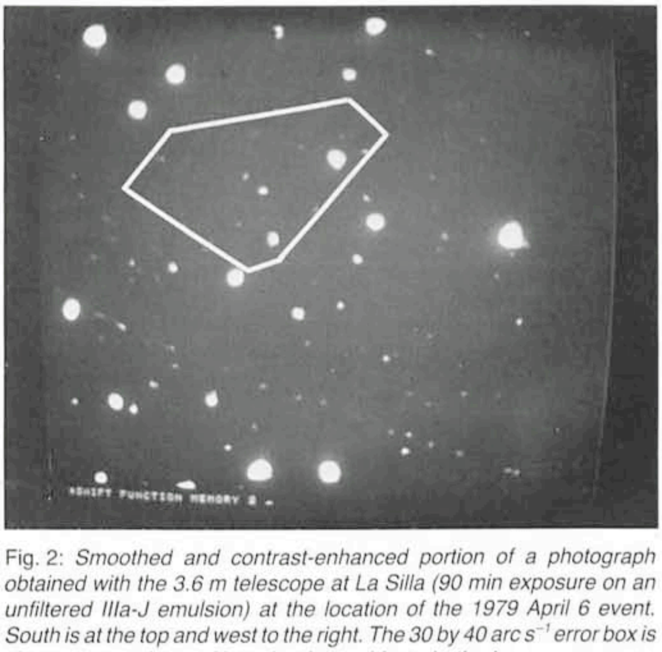

Fig. 2: *Smoothed and contrast-enhanced portion of a photograph obtained with the 3.6 m telescope at La Silla (90 min exposure on an unfiltered IIIa-J emulsion) at the location of the 1979 April 6 event. South is at the top and west to the right. The 30 by 40 arc s^{-1} error box is shown as a polygon. Note the three objects in the box.*

* The Venera probes and the Prognoz satellite carry detectors developped at CESR, Toulouse.

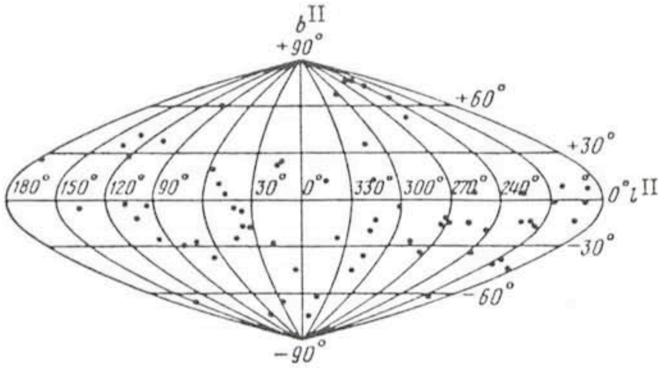

Fig. 3: *The positions of the 69 γ-ray burst sources now roughly localized, shown in galactic coordinates (from Mazets et. al. 1980).*

If we take into account the known surface densities of faint stars and galaxies at different magnitudes near the galactic pole reported, among others, by Tyson and Jarvis (1979) we find that there should be about 37,800 objects per square degree with magnitudes between 22 and 24. Therefore we would expect between 1 and 3 such objects (Poisson statistics!) in the 800 arcsec^2 box which would not appear in the Schmidt plates. Moreover, most of the faintest should be galaxies.

In an attempt to find if any of these faint objects are galactic stars, we plan, during the coming months, to obtain magnitudes, colours and image profiles by continuing photography at the 3.6 m prime focus and also by making electronographic (McMullan camera) and electronic (CCD camera) observations.

The Nature of the Bursts

The spatial distribution of the now about 70 roughly localized bursts is more or less isotropic (see Figure 3). This could indicate either a very local origin (nearby low-luminositiy optical objects) or an extragalactic origin (associated with faraway galaxies). The intensity-vs-number (so-called logN-logS) distribution (see Figure 4) may give some indication in favour of a local origin since, after following a $S^{-1.5}$ power law, it flattens out at low intensities much more than would be expected from instrumental selection effects alone.

The very short time scales sometimes exhibited by gamma-ray bursts (see Fig. 1) imply very compact sources like neutron stars (the rise time of the 1979 March 5 event was less than 200 microseconds, suggesting a source size of less than 60 km!). These arguments have recently been used by some authors (R. Sunyaev, S. Bonazzola) to propose for gamma-ray bursters a model somewhat similar to that currently accepted for the recurrent X-ray bursters (see THE MESSENGER No. 23) which differ from gamma-ray bursters in intensity, spectrum and recurrence but have time scales analogous to some gamma-ray bursts. The gamma-ray bursts would be due to thermonuclear flashes ($3\ He^4 \rightarrow C^{12} + \gamma$) occurring in the surface layers of neutron stars which undergo a very slow but steady accretion of matter, presumably in binary systems.

Although nearby galactic neutron stars seem the most plausible candidates for gamma-ray burst sources, the alternative suggestion of an extragalactic (albeit neutron-star-based) origin for the 1979 March 5 event has not yet been completely abandoned by some theorists in spite of the rather incredible values of burst luminosities that it would imply ($3\ 10^{44}$ ergs/sec if at the distance of the LMC). Therefore, optical identification of these sources is still a crucial task. And it requires a detailed, time-consuming study of all the faint optical objects in the small error boxes derived for some of the best-studied gamma-ray bursts.

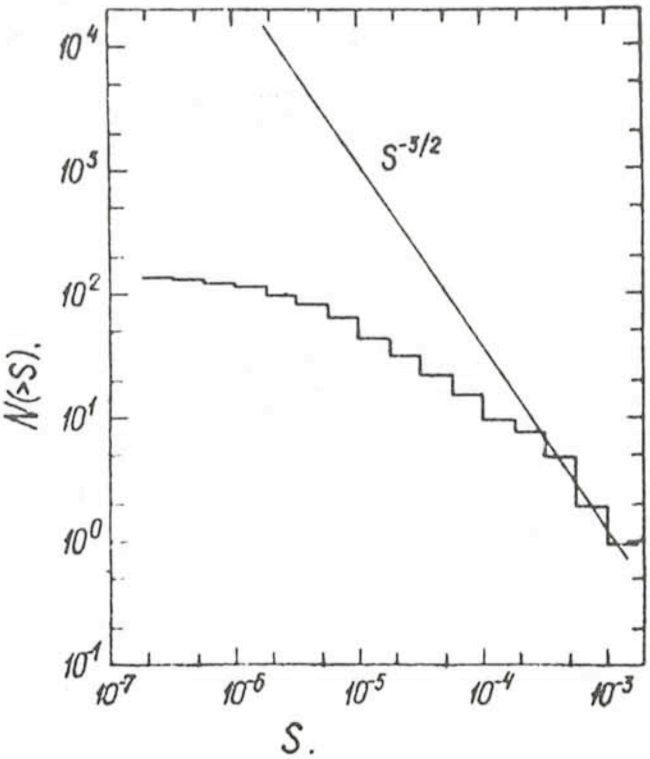

Fig. 4: *The log N-log S distribution for the 43 γ-ray bursts recorded from September 1978 to February 1980 by the Russian Konus experiment on the Venera 11 and 12 spacecraft (from Mazets et. al. 1980).*

References

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ESO Conference on the "Scientific Importance of High Angular Resolution at Infrared and Optical Wavelengths"

The conference on the "Scientific Importance of High Angular Resolution at Infrared and Optical Wavelengths", announced in the last issue of the MESSENGER, took place in the ESO headquarters at Garching on 24–27 March 1981. It was attended by 91 participants from 13 countries.

The aim of this conference was to help deciding if the large telescope of the future should be made of a single 16 m mirror or of several smaller aperture telescopes forming an interferometer. Accordingly, present achievements of both